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National Hydrology Research Institute
Institut national de recherche en hydrologie

Environment CANADA Environnement
2056174K VOL 87 ISS 6 870331
EXC # 001
GB 707 N42
NHRI CONTRIBUTION

OOFF

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FACILITY FOR INDOOR AQUIFER TESTING

Design Report
Progress to March 31, 1987

Unpublished Report

NHRI Unpublished Report
Contribution No. 87006

MANAGEMENT PERSPECTIVE

The design of the Facility for Indoor Aquifer Testing (F.I.A.T.) is an ongoing project. The facility will permit large scale examination of ground water/precipitation/soil/waste interactions in a controlled environment. The initial experiment will investigate the stability of activated fluidized bed combustion wastes under proposed disposal conditions. The F.I.A.T. consists of a large tank (8 ft. in dimater and 15 ft. high) with ports for sampling liquids and solids, and a system for simulating rainfall. This report details the developments for the period December 1986 to March 31, 1987, and will permit interested parties to evaluate the capabilities and limitations of the Facility.

PERSPECTIVE DE GESTION

La conception de l'installation pour les essais aquifères intérieurs est un projet en cours. Cette installation permettra l'examen sur une grande échelle des interactions entre les eaux souterraines, les précipitations, le sol et les déchets dans des conditions contrôlées. La première expérience portera sur la stabilité des déchets de combustion en lit fluidisé activés dans les conditions d'élimination proposées. L'installation comprend un grand réservoir (8 pieds de diamètre et 15 pieds de hauteur) muni d'orifices pour l'échantillonnage des liquides et des solides et d'un système pour simuler les précipitations. Ce rapport décrit les progrès réalisés entre décembre 1986 et le 31 mars 1987; il permettra aux intéressés d'évaluer les possibilités et les limites de l'installation.

ABSTRACT

This report details the design of the Facility for Indoor Aquifer Testing (F.I.A.T.) for the period December 1986 to March 31, 1987. It does not, except where required for continuity, include all options considered during the design phase. The F.I.A.T. consists of five major subsystems: the tank body, solid/liquid sampling ports, soil moisture/ground water collection system, precipitation simulator, and the drain/ground water table manipulation system. The report will allow interested parties to evaluate the design and materials used in the F.I.A.T. subsystems and indicates the capabilities and limitations of each subsystem. A list of materials is included for each subsystem. The design of a collector tank used to verify design assumptions on a smaller scale is also included.

RESUME

Ce rapport décrit la conception de l'installation pour les essais aquifères intérieurs pour la période allant de décembre 1986 au 31 mars 1987. Il ne renferme pas, à moins que ce ne soit nécessaire aux fins de continuité, toutes les options étudiées pendant la phase de conception. L'installation comprend cinq grands sous-systèmes: le réservoir, les orifices pour l'échantillonnage des liquides et des solides, le système de collecte des eaux souterraines/humidité du sol, le simulateur de précipitations et le drain/système de manipulation de la nappe phréatique. Le rapport permettra aux intéressés d'évaluer la conception et les matériaux utilisés dans les sous-systèmes de l'installation et indique les possibilités et les limites de chacun. On y trouve également une liste des matériaux pour chaque sous-système ainsi que le plan d'un réservoir collecteur utilisé pour confirmer les hypothèses de conception sur une plus petite échelle.

SUMMARY

This report details the final design of the Facility for Indoor Aquifer Testing. The F.I.A.T. consists of five major subsystems: the tank body, solid/liquid sampling ports, soil moisture/ground water collection system, precipitation simulator, and the drain/ground water table manipulation system.

Also included in the report is the design for the collector test tank which is used to verify design assumptions on a smaller scale.

Each section includes a materials list to facilitate the assessment of the chemical/physical compatability of the subsystems with any specified use.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the financial support of the Oil, Gas & Energy Division, Industrial Programs Branch, E.P.S., as well as the technical support provided by the Instrument Technology Section, N.H.R.C.

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1.0 Introduction

The purpose of the Facility for Indoor Aquifer Testing is to allow study of the reactions between infiltrating waters, waste products, soils, and ground water under carefully controlled conditions. The F.I.A.T. design follows the basic concept of column tests on a much larger scale - a tank 4.6m high by 2.44m in diameter. The large scale of the F.I.A.T. eliminates some of the problems associated with column tests. The edge effects which create difficulties in column tests, for example, are not a problem with the FIAT.

The first experiment using the F.I.A.T. will simulate subsurface disposal conditions for fluidized bed combustion wastes (ref. Environmental Protection Service, 1986, M.M. Dillon Ltd., September, 1985). The waste site conditions will be scaled down by a factor of ten. This will mean applying a layer of waste 80 cm to 100 cm thick on the surface of the soil. All conditions in the tank will be adjusted to provide a worst case scenario: the clay liner and cap used at the waste disposal site will not be used in the simulation.

The facility provides the capability of sampling soil moisture and ground water samples using screened Teflon samplers installed at ten predetermined depths. At the conclusion of the experiment, horizontal cores at the same depth as the Teflon samplers can be removed for analysis and comparison.

The F.I.A.T. consists of five major subsystems: the tank body, solid/liquid sample ports, soil moisture/ground water collection system, precipitation simulator, and the drain/ground water table manipulation system. In this report, each of these subsystems is described in a separate section and each section includes a materials list to facilitate the assessment of the chemical/physical compatability with any prospective use. Also included in the report is a section on the design for the collector test tank which is used to verify design assumptions on a smaller scale.

2.0 Tank Body Design

A cylindrical tank 4.6m high by 2.44m in diameter was chosen to permit a reasonable number of samples (10) to be collected at different depths without cross sample interference. (figure 1)

The tank is constructed of fiberglass (DION 6694 resin) in two sections 2.3m high. The two sections are attached with type 316 stainless steel bolts on 75mm centres through a 100mm rubber flange.

2.1 Additional Considerations

Because the fiberglass is translucent, several coats of opaque paint will be applied to the exterior in order to eliminate light activated microbiological activity inside the tank.

2.2 Materials

Materials used in the tank construction were chosen for their chemical inertness to as wide a variety of chemicals as possible, and for their workability and durability. The body of the tank is glass reinforced polyester resin: the resin used was DION COR-RES 6694 (Koppers Co. Inc.). The tank was manufactured by Brekmar Industries of Saskatoon to a design provided by GWD. Specifications of the chemical inertness of the material are available from Koppers Co. Leachate tests on samples of the fiberglass used in the tank construction will be conducted to determine the precise leaching characteristics.

Other items in contact with the materials being tested in the tank are the solid/liquid sampling ports (detailed in section 3) and the rubber gasket between the two sections. Potential contamination due to the gasket will be eliminated by facing the inside surface of the gasket with Teflon tape before assembly of the sections.

3.0 Sampling Ports

The sampling ports (figure 2) are an integral part of the tank construction and serve four distinct purposes depending on their location in the tank. All ports are physically identical -- 50 mm threaded P.V.C. female fittings bossed into the fiberglass during manufacture of the tank. The ports are fitted with appropriate plugs or adapters for their designated use.

i) Liquid sample ports (3) permit the removal of soil moisture and ground water samples from the collectors while the experiment is underway. These ports allow the 6 mm Teflon sample tubing (section 4) to exit from the tank interior 150 mm from the bottom.

ii) Drain ports (2) allow drainage of infiltrating water or water table manipulation during the experiment. The 25 mm polyethylene hose from the drain (section 6) is routed through a bulkhead adapter to exit the tank at the 150 mm level.

iii) Instrumentation port (1) to allow entry/exit of tensiometer instrumentation (section 4) at the 150 mm level.

iv) Solids sample ports (10) permit the removal of undisturbed representative solids samples at the conclusion of the experiment. Fitted with 50 mm plugs, these ports are spaced evenly around the circumference of the tank 766 mm on centre. Vertical spacing is shown in figure 3. At the conclusion of an experiment, the plugs will be removed, a core tube inserted and a sample withdrawn.

3.1 Materials

All ports, plugs, and adapters are P.V.C.

4.0 Soil Moisture/Ground Water Collection System

The soil moisture/ground water collection system consists of ten Teflon open faced filter holders with a support structure and pump/control system for each filter unit. Three main criteria were considered when designing the collector system:

i) Materials in contact with the water sample and the experimental material in the tank should be as chemically inert as possible.

ii) The collection system should interfere as little as possible with the flow regime. It should neither obstruct the flow nor alter the water table. If a sampler is pumped at too low a rate, for example, a perched water table may be formed above the filter unit. Pumping at too high a rate could create a cone of depression around the sampler.

These considerations were addressed in the following ways:

1) To minimize chemical contamination, all material in contact with the liquid sample is Teflon TFE, PTFE, or FEP. This includes the samplers (figure 4) as well as all tubing and connectors carrying liquid.

2) The support structures (figure 4) are installed vertically in a circular pattern (figure 5). The support structures are designed so that an open faced filter (modified Canadawide Scientific 4290-11) can be installed. The 50 mm filter/collector and the support structure have the same outside diameter.

The volume of sample that can be withdrawn per unit time equals the area of the collector multiplied by the precipitation rate per unit time. This is true only under saturated conditions, but it serves as a useful guide when calculating the sample volumes obtainable.

3) The pump control system utilizes one adjustable peristaltic pump for each sampler. Each pump is controlled individually by a soil tensiometric balance system in order to avoid interference with the flow patterns. The system consists of a soil tensiometer placed adjacent to the collector and another tensiometer placed 250 mm away in the same horizontal plane. The tubing from the two tensiometers exits the tank through the instrumentation port at the 150 mm level. Each pair of tensiometers is connected to opposite sides of a pressure transducer, which results in an electrical output (+,-) proportional to the difference in soil moisture between the two points. The pump speed is adjusted electronically until the tensiometer readings balance. The soil moisture level in the immediate area around the sampler will then be the same as that at a distance from the sampler and no disruption to flow patterns will result.

4.1 Materials

Collectors	- Teflon PTFE, TFE (modified Canadawide Scientific 4290-11)
Support	- Series 160 40 mm P.V.C. pipe and fittings
Base	- 20 mm Fir plywood covered with 2 mil plastic
Sample tubing	- Teflon FEP, 6 mm
Hardware	- Type 316 stainless steel

5.0 Precipitation Simulator

The precipitation simulator must allow the even and controlled application of precipitation which has a known chemical composition.

Even application over the surface of the tank is important because a number of the soil moisutre collectors are very near the surface. For these shallow collectors, uneven application would result in unrepresentative samples. For deeper collectors the effects of uneven application would be less critical.

The current design for the precipitation simulator specifies on the use of commercial six outlet drip emitters (Toro 700-06 0.5 U.S.G.P.H.). These are small diaphragm type constant flow valves requiring between 70kN/m^2 and 175kN/m^2 operating pressure. Mounting each emitter outlet on a 20cm grid was considered to be the most practical. A grid of 109 emitters is required to achieve 400cm^2 coverage per emitter. This grid is illustrated in figure 7.

The maximum amount of rainfall that can be applied, then, is calculated as follows:

Total volume/hour = (109 emitters)(0.5USGPH)(3.785L/USG)(1000cm^3/L)
Dividing this by the surface area of the tank (4.67e4cm^2) results in a maximum precipitation rate of 4.4cm/hour at a flowrate of 206L/hour.

The area each drip emitter must cover ($400cm^2$) is excessive for a point drop system. A method of moving the emitter outlet tubing (figure 8), however, proved feasible. Two linear actuators (SKF CARR 22 with adjustable limit switches) set up on a horizontal X-Y plane are slowly extended and retracted a distance of 20 cm. The actuators are mechanically linked to a suspended emitter outlet platform below the main support platform. This motion was simulated (B. Christie, Personal communication, March'87) with an electronic model consisting of a storage type oscilloscope and two signal generators (figure 9). Because of the constant velocity of the triangle wave trace, triangle waveforms (linear) with an X-Y frequency ratio of 3:5 were chosen over sinusoidal (rotational) wave form.

In the initial test the quantities used will simulate the average precipitation at the proposed waste disposal site. A preliminary digital simulation of the F.I.A.T. (Vandenberg 1987, page 2) indicates maximum infiltration rates through the waste of less than one cm per hour. Preliminary wetting trials carried out on the waste suggest infiltration rates may decrease with time due to the hydration of the CaO contained in the waste. As the output of the precipitation simulator exceeds the infiltration capacity of the waste, a pump intervalometer system (Section 5.1) will be used to reduce application quantities.

5.1 Precipitation Storage

A water supply of controlled, known chemical composition is required to provide precipitation for the system (figure 10). The precipitation water stored in the 2270L primary storage tank will be pumped to a 70L head tank for secondary storage. The precipitation pump will then deliver a set volume (46.7L) to the emitter array. The timing of the head tank discharge cycle will be controlled by a pump intervalometer. One cycle of the head tank will result in the equivalent precipitation of 1cm of rain applied to the F.I.A.T.

The storage capacity of the 2270L primary tank allows the precipitation simulator to deliver 486mm of rainfall to the F.I.A.T. before the storage tank needs refilling. This is approximately half the volume required to simulate one year of average precipitation in the coastal areas of New Brunswick (1000mm/yr).

Precipitation Simulator-continued

5.2 Materials

No material which will be in contact with the precipitation contains metal.

Primary and secondary storage tanks
- high density polyethylene

Piping - polyethylene

Fittings - nylon

Emitters - PVC with synthetic rubber diaphragm

Pumps (wetted parts) - nylon/plastic

6.0 Drain/Ground Water Manipulation System

The function of the drain/ground water table manipulation system is to provide control of the water table within the tank (figure 11). Ground water table manipulation can be achieved by the use of an overflow head tank connected to the drain and raised to the desired level. To simulate unsaturated conditions throughout the tank, the systems may be either free draining or pumped.

The system consists of 40 mm slotted PVC pipe (no. 10 slot) assembled in a star shaped pattern 300 mm from the bottom of the tank. The pipe is set in 6 mm (100% passing) well-packing sand (depth = 750 mm). A circular header of 25 mm polyethylene hose connects the screen sections. The hose then slopes downward to exit the tank at the 150 mm level.

Materials

Slotted screen - 40 mm PVC

Header - 25 mm polyethylene hose

Hose clamps - type 316 stainless steel

Fittings - PVC and nylon

7.0 Floor Loading

When the physical space available for the Test facility was considered in the design of the FIAT, two criteria were of primary importance. First, no one part could exceed the capacity of the overhead winch (3.5 tons). Second, the floor load limits could not be exceeded.

The floor loading was calculated as follows:

volume of tank = $TTr^2h = TT(2.44m/2)^2(4.6m) = 21.6m^3$

Filling the tank with aquifer materials of the maximum specific weight ($22kN/m^3$) results in a total weight of

$(21.6m^3)(22kN/m^2) = 475.2kN$

The resulting load, obtained by dividing the total weight by the area of the base, is

$475.2kN/(TT(2.44m/2)^2) = 101.7kN/m^2$

This value exceeds by a factor of 8 the floor loading maximum of $12kN/m^2$. A reduction of this magnitude in the size of the tank would not have been feasible, so an alternative solution was sought. To distribute the weight over a larger area, a concrete "housekeeping pad" was designed by Cochrane Lavalin Consultants (ref. Cochrane Lavalin Consulting Engineers, February 1987). The pad is 250 mm thick by 4000 mm square. The existing floor slab on grade was sawcut through to the subgrade resulting in a floating pad (not physically connected to the building) underlying the housekeeping pad. Thus even though settling may occur, differential settling will be avoided, as care was taken to avoid having part of the pad resting on a wall footing.

The resulting load on the pad is now the total weight of the tank (475.2kN) divided by the area of the floating pad ($16m^2$): that is $29.7kN/m^2$. The amount of settling which will occur depends on the degree of compaction of the subgrade during construction of the building.

8.0 Collector Test Tank

During the design phase of the F.I.A.T. it was apparent that small scale, in-situ testing of materials and methods was desirable. The requirement for pilot testing of soil moisture samplers, precipitation simulators, soil tensiometers, and pumping control systems under controlled, accessible conditions resulted in the design/construction of a collector test tank.

The tank is fabricated from 60 cm fiberglass pipe 120 cm long. A removable base was attached to the bottom of the pipe to allow easy access. The tank is spray coated with DION 6694 resin to simulate the material used in the F.I.A.T. construction.

The collector supports (figure 4) are installed 220 mm apart. The soil moisture collectors under test are installed 550mm vertically from the base of the tank. The collector sample tubing exits the tank through a bulkhead fitting 100 mm from the base (figure 12). Two 400 mm lengths of 50 mm slotted PVC pipe set in 200 mm of well sand serve as a drain.

8.1 Precipitation Simulation - Collector Test Tank

The precipitation simulator for the collector test tank (C.T.T.) is similar to the F.I.A.T. simulator in that it uses drip emitters to provide evenly spaced distribution. The main difference between the two is that the C.T.T. simulator uses 24 single outlet 1.9 L/hr emitters on a 100 mm fixed grid. These 24 emitters deliver 40 L/hr to the surface of the tank, equivalent to a precipitation rate of 15.5 cm/hr. As in the FIAT precipitation simulater, the pump is controlled by a pump intervalometer which allows selection of any precipitation rate up to 15.5 cm/hr. The materials used in the collector test tank are identical to those used in the F.I.A.T.

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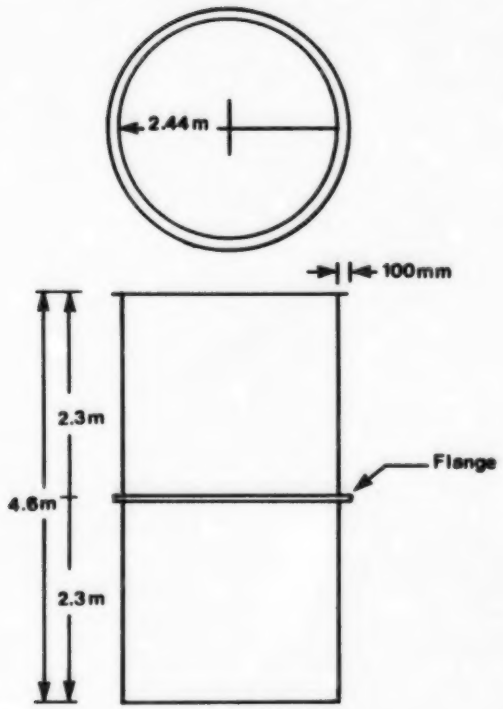

Figure 1. Tank Dimensions

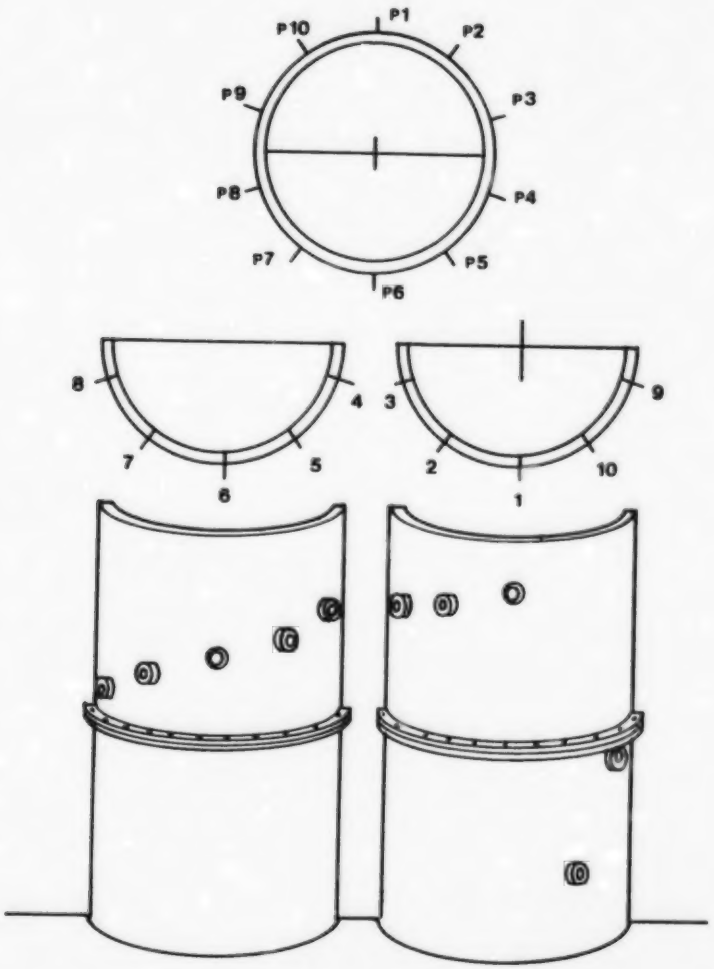

Figure 2. Solid Sampling Ports

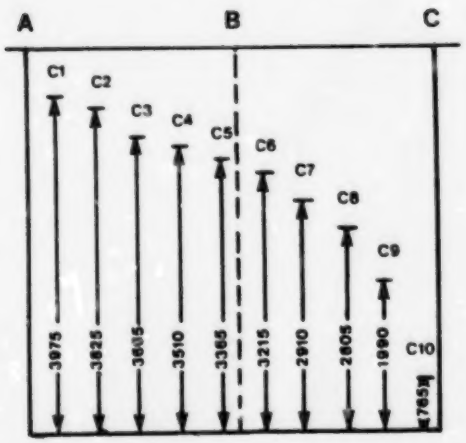

Figure 3. Vertical Elevations of Solid Sampling Ports and Soil Moisture/Ground Water Collectors

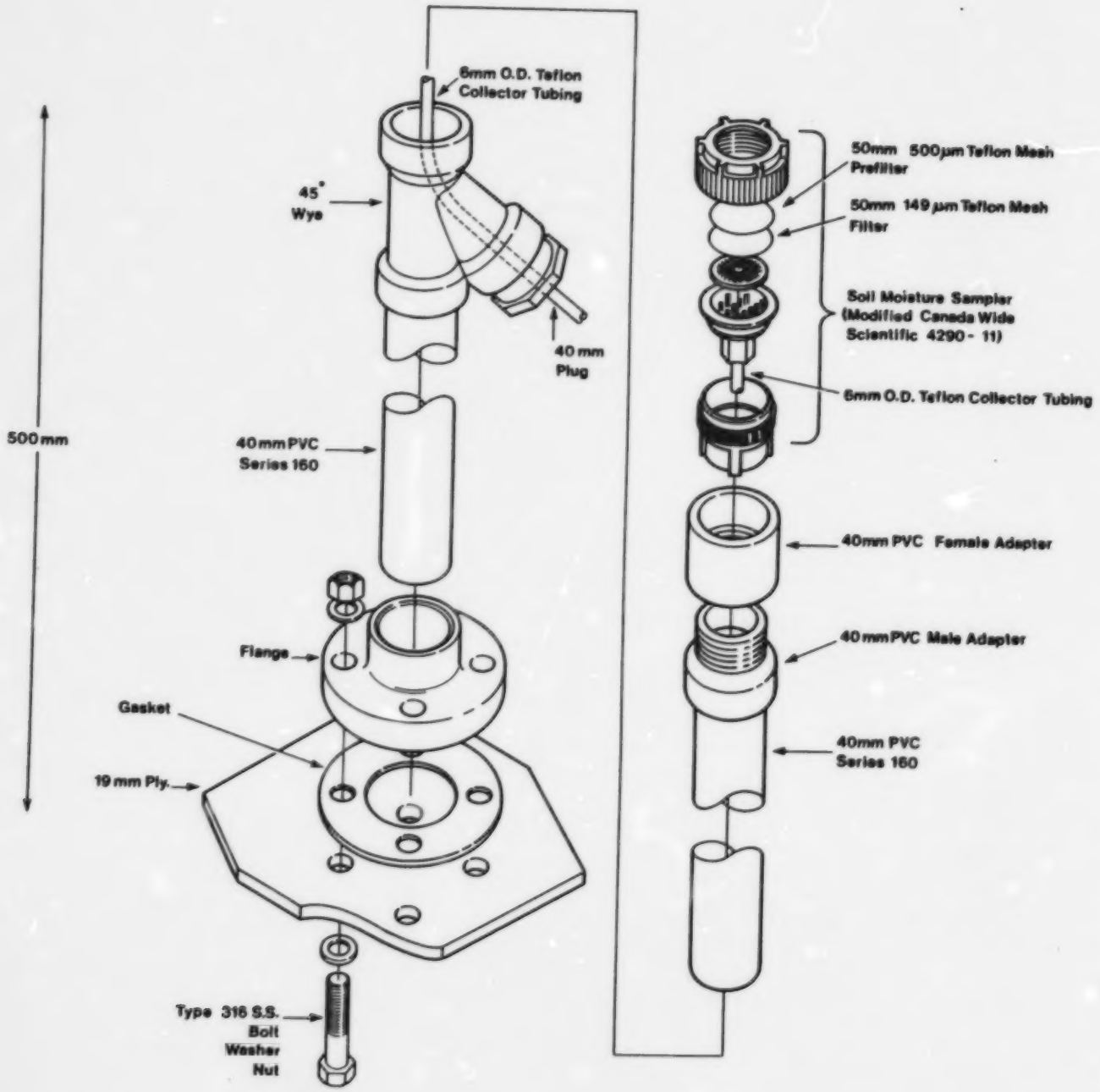

Figure 4. Soil Moisture/Ground Water Collector and Support Structure

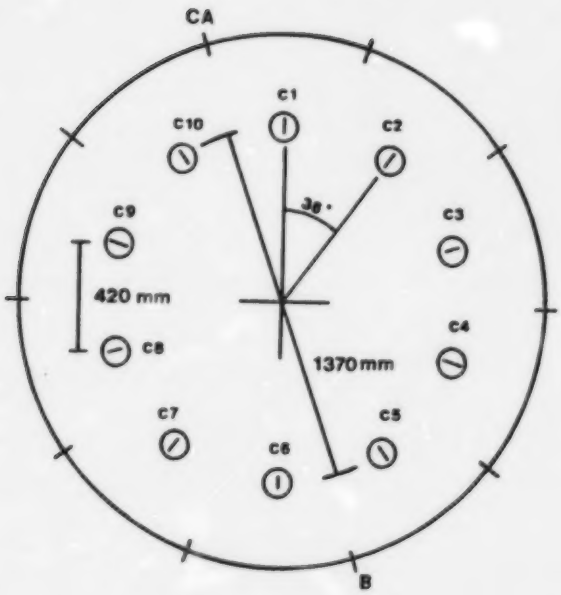

Figure 5. Soil Moisture/Ground Water Sampler Locations-Plan View

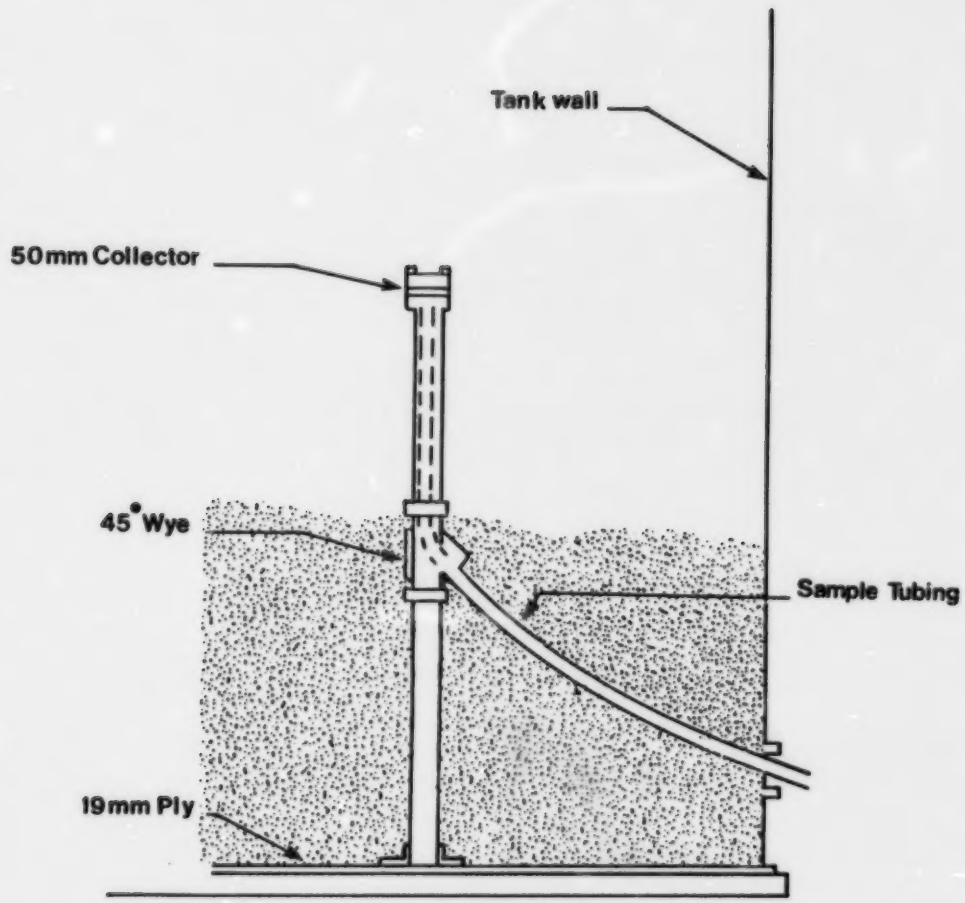

Figure 6. Typical Soil Moisture/Ground Water Sampler Detail

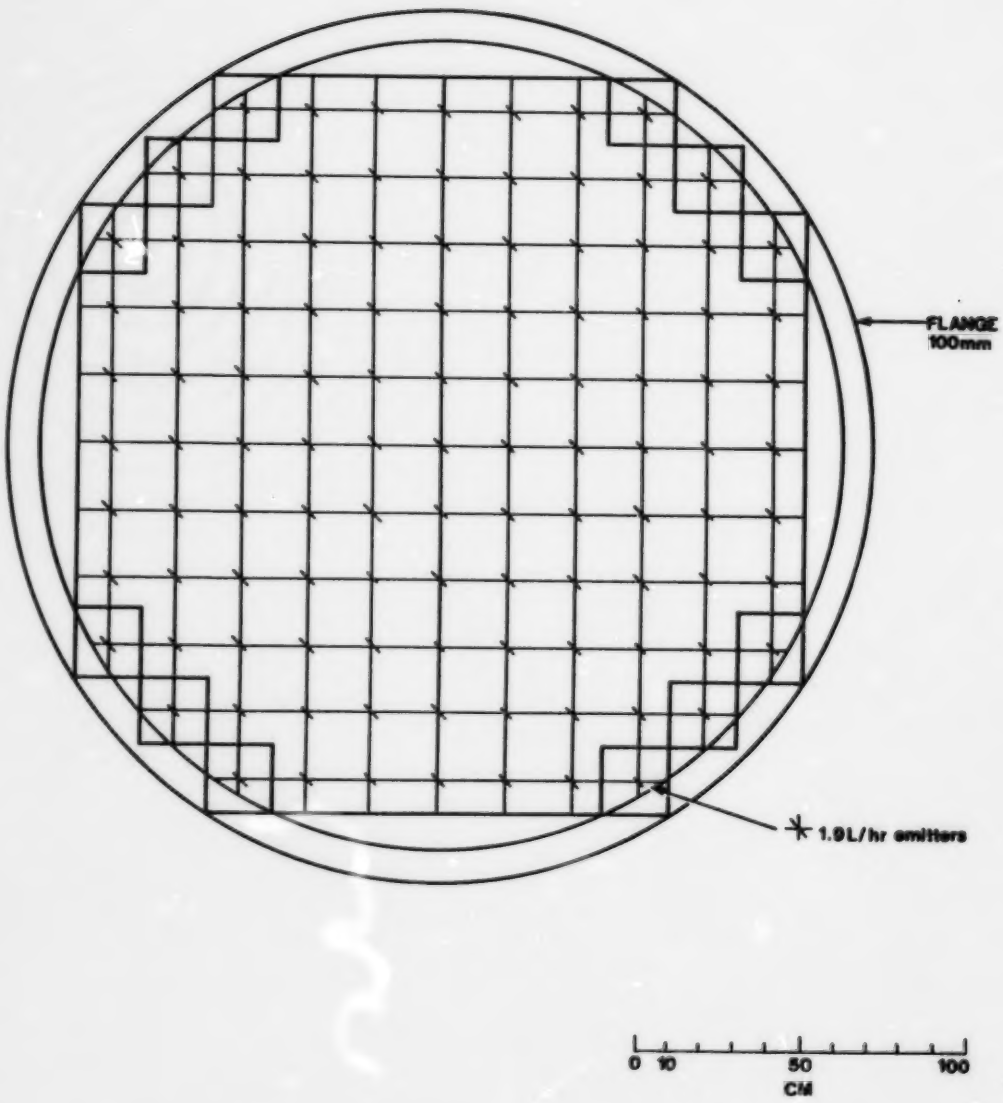

Figure 7. Drip Emitter Grid Detail

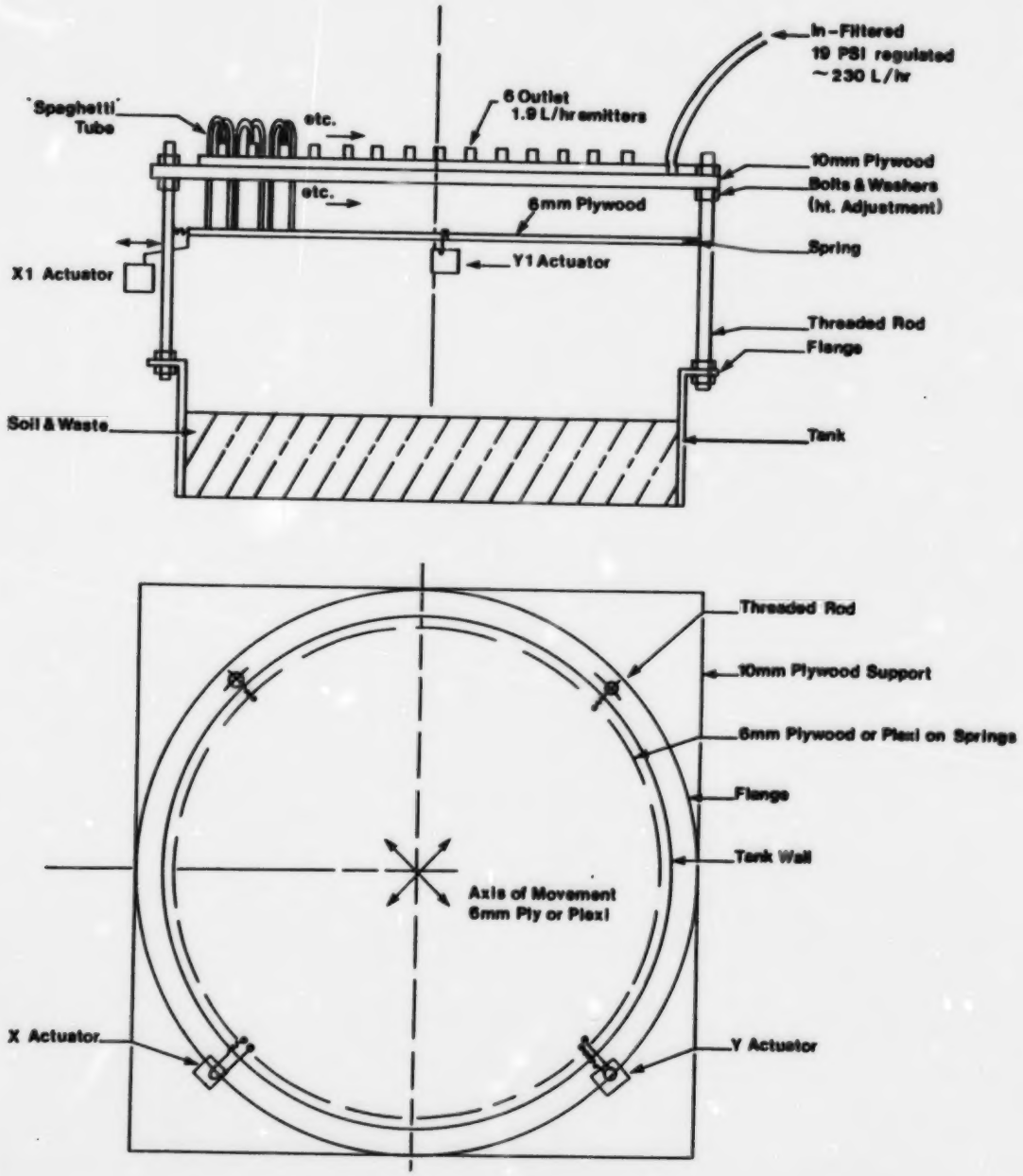

Figure 8. Precipitation Simulator Detail

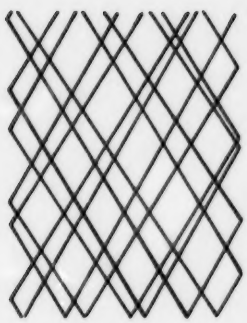

Figure 9. Typical Precipitation Simulator Pattern

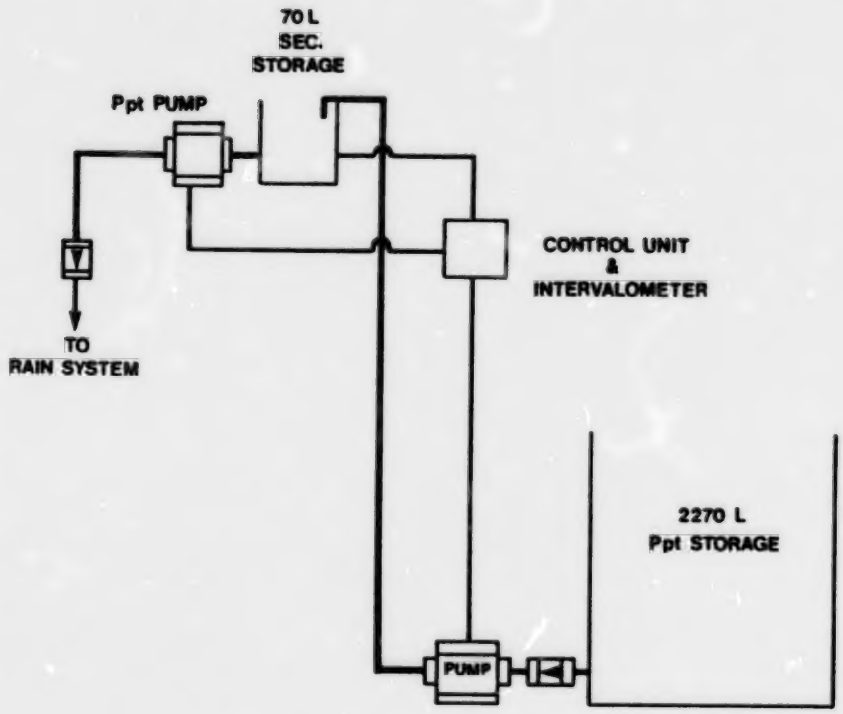

Figure 10. Precipitation Storage and Delivery

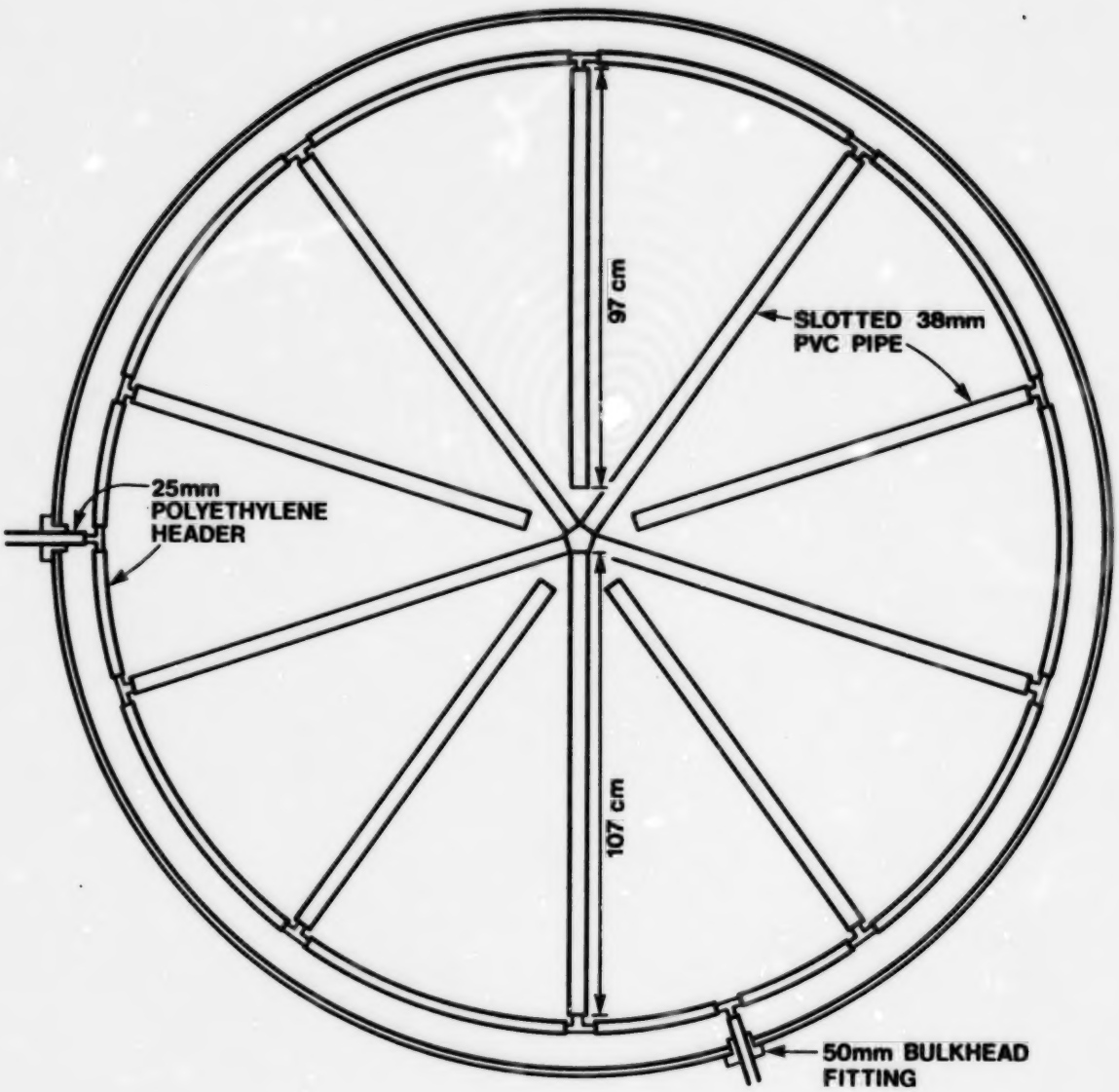

Figure 11. Drain/Ground Water Manipulation System

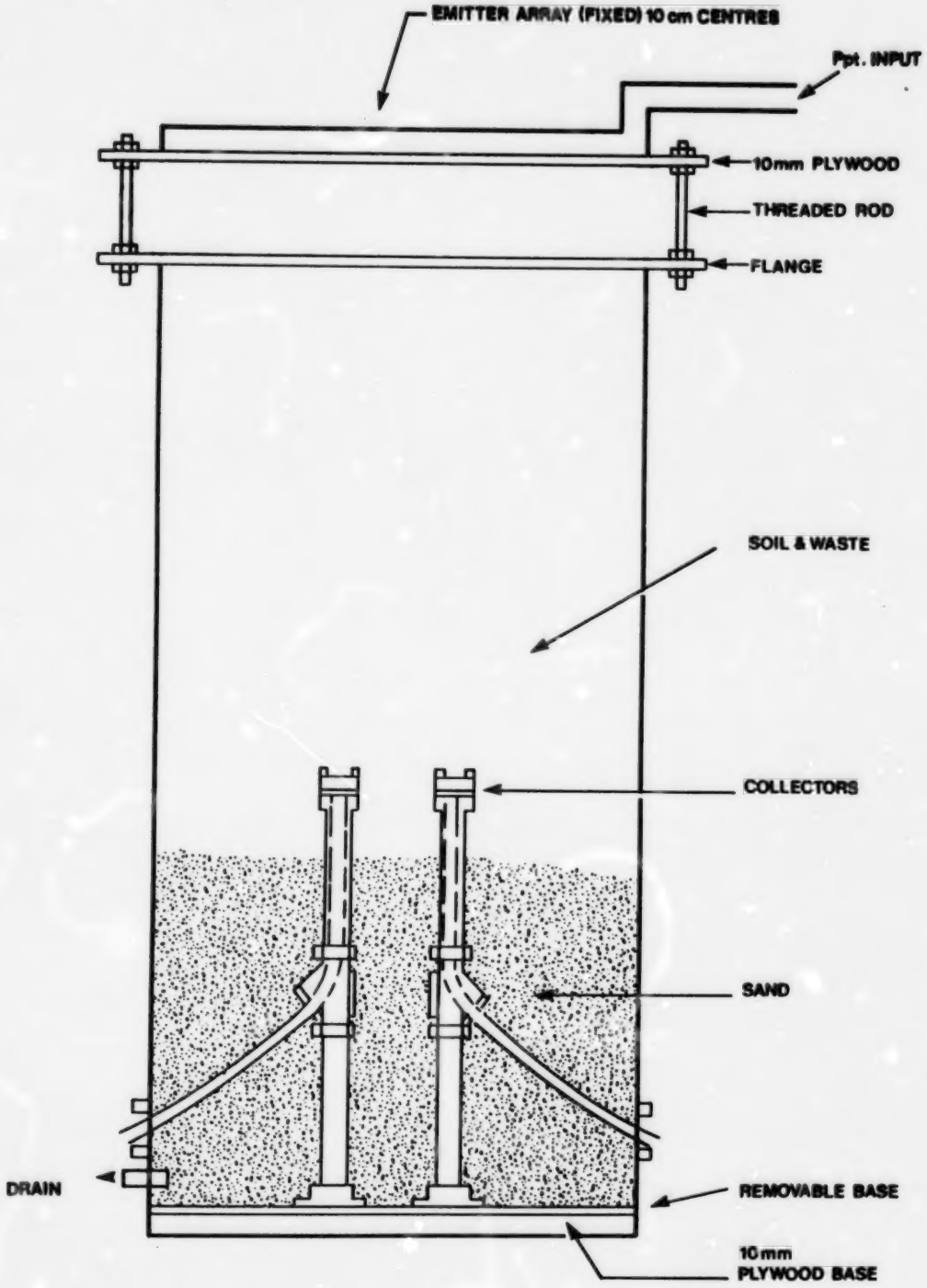

Figure 12. Collector Test Tank